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W. Petruk and R.G. Pinard

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# IMAGE ANALYSIS OF GALENA IN SAMPLES FROM THE KIDD CREEK COPPER CIRCUIT

by

W. Petruk and R.G. Pinard

## SUMMARY OF RESULTS

Two suites of samples from the copper circuits of two divisions in the Kidd Creek plant were studied to determine the reason for the high lead content of the copper concentrate. The samples were studied with a Quantinet 720 image analyser to determine the proportions and size distribution of the free and unliberated galena grains. The results show that the main reason for the high lead content in the copper concentrate is that, in the copper cleaner circuits, free galena tends to be concentrated with chalcopyrite whereas the unliberated galena tends to be rejected. The obvious solution is to direct the free galena to the copper rougher tailings thereby preventing free galena from entering the cleaner circuit. There was no relationship between size of free galena grains and amount of free galena in the copper concentrate.

# ANALYSE PAR IMAGE DE LA GALÈNE À PARTIR D'ÉCHANTILLONS DU CIRCUIT DE CUIVRE DE KIDD CREEK

par

W. Petruk et R.G. Pinard

## RÉSUMÉ DES RÉSULTATS

On a étudié deux ensembles d'échantillons de circuits de cuivre de deux divisions de l'usine de Kidd Creek, afin de déterminer pourquoi le concentré de cuivre contient une grande quantité de plomb. On a fait l'étude des échantillons à l'aide de l'analyseur par image Quantinet 700 dans le but de déterminer le pourcentage et la distribution des dimensions de grains de galène libre et non libre. Les résultats indiquent que le concentré de cuivre contient une quantité élevée de plomb principalement parce que, dans les circuits de lavage du cuivre, la galène libre à se concentrer avec la chalcopyrite alors que la galène non libre à tendance à tendance à être rejetée. Évidemment, la solution à ce problème consiste à diriger la galène libre vers les résidus de cuivre grossiers, empêchant de cette façon la galène d'entrer dans le circuit de nettoyage. On n'a pu trouver de relation entre la dimension des grains de galène et la teneur en galène libre du concentré de cuivre.

## INTRODUCTION

A comprehensive program of applied mineralogy is being done in the Mineral Sciences Laboratories, on a cost-recovery basis, for Kidd Creek Mines Ltd. The work reported here was carried out by image analysis.

Two series of samples from the copper circuit of the Kidd Creek plant were received from Dr. J.D. Scott, senior staff scientist, in February 1983. One set was the "D Division on C ore" samples numbered 5852 to 5867, the other was "B Division on A ore samples" and numbered 6219 to 6234. Dr. Scott requested that the samples be analysed to determine the percentages of free and unliberated galena grains in order to determine the reason for the loss of lead in the copper concentrates.

## CHEMICAL ANALYSES AND METAL RECOVERIES

The chemical analyses, metal recoveries and wt % for each stream were supplied by Dr. Scott (Tables 1 and 2).

### GALENA LIBERATION

The percentage of galena as free grains, as unliberated grains in pyrite, and as unliberated grains in sphalerite were determined with the Quantinet 720 image analyser (Table 3). The quantity of galena as unliberated grains in chalcopyrite was less than 5% of the galena, hence the values were not measured separately but were combined with the values for unliberated grains in pyrite. The amount of galena in samples from "B Division on A ore" is very low, therefore, the image analysis data have a large error of analysis. Nevertheless it was found to be accurate enough to show the trend for galena concentration.

Lead assays due to free galena, unliberated galena in pyrite, and unliberated galena in sphalerite were calculated by multiplying the % free or unliberated galena by the lead assay for each sample.

A material balance was performed for the free and unliberated galena using the MATBAL3 program. To perform the materials balance the weight % of each stream was fixed to the value supplied by Dr. Scott and the lead assay due to either free or unliberated grains was allowed to adjust. The adjusted (balanced) values were back-calculated to % of free and unliberated grains and are included in Table 3. The materials balance

calculation also gave the recovery of lead, of free galena, and of unliberated galena grains (Tables 4 and 5). The recoveries show that for the "D Division on C ore" 69.3% of the galena in the rougher mill feed was as free grains, and 19.3% of the free galena was lost to the rougher concentrate. The rougher concentrate is combined with a circulating load (midds concentrate of the cleaner circuit) for a total of 36.7% of the lead in the mill feed being as free galena in the cleaner circuit feed (cleaner 1 feed). 12.5% of the lead in the mill feed is lost as free galena grains to the copper concentrate and this contributes 2.17% Pb to the lead assay of 3.1% Pb in the copper concentrate. Stated another way, 65% (12.5/19.3) of the free galena directed to the cleaner circuit from the rougher flotation cells was lost to the copper concentrate. By contrast, only 35% of the unliberated galena in pyrite and 20% of the unliberated galena in sphalerite in the rougher concentrate was lost to the copper concentrate. Hence middling galena tends to be rejected from the copper cleaner circuit more efficiently than free galena. These results show that the main loss of lead to the copper concentrate is due to a loss of free galena grains. In fact most of these free grains were initially lost to the rougher circuit concentrate and were subsequently directed to the cleaner circuit where the free galena stayed with chalcopyrite. The obvious way to correct this is to recover most of the free galena in the rougher tailing. Size distribution of the galena grains, given in Figures 1 and 2 and Tables 7-10 do not indicate any trends with respect to grain size.

The samples of the "B Division of the A ore" contained much less galena, and the flowsheet is considerably different. The same assessment, however, can be made for the B Division cleaner circuit as for the D Division cleaner circuit; 71.2% of the galena in the mill feed was as free grains. Due to a circulating load, 115.7% of the lead in the mill feed was as free galena grains is the cleaner circuit feed and 59.2% of the free galena in the mill feed or 51% in the cleaner circuit feed was lost to the copper concentrate. By contrast, 4% of the unliberated galena in pyrite and 8% of the unliberated galena in sphalerite in the cleaner circuit feed were lost to the copper concentrate. These results show that, as in the "D Division on C ore", the main loss of lead in the "B Division on A ore" copper concentrate is free galena. This is because the free galena that enters the copper cleaner circuit tends to be held with chalcopyrite and

lost in the copper concentrate. On the other hand, the unliberated galena tends to be discarded to cleaner tailings. Size distribution of the galena in "B division of A ore" are given in Figures 3 and 4 and Tables 11-14.

The recovery of free galena, unliberated galena, Pb, Cu, Ag and weight of material by each cell and by the cleaner circuit were calculated by dividing the recovery in the concentrate by the amount in the feed (Table 6). The results confirm that, in the cleaner circuits, there was a higher recovery of free galena than of unliberated galena; in particular for the D division on "C" ore, the recovery of free galena was equal to the recovery of copper.

Table 6 shows that the recovery of silver was less than the recovery of copper in every cell. It was 85% of the copper recovery in the D and B division cleaner circuits and D division rougher cell, and 76% for the B division rougher-scavenger circuit. To define the behaviour of silver it is necessary to identify the silver carrier in each product and determine the proportion of silver in each carrier. No mineralogy was done on the silver in this study.

The percentages of chalcopyrite, sphalerite and galena that occur as free grains were also determined for sample 5856, which is the midds concentrate. The results show that 78% of the chalcopyrite, 74% of the sphalerite and 59% of the galena were present as free grains. The relative quantities of chalcopyrite to sphalerite in the sample were analysed as 1:0.57 with the Quantimet 720 image analyser and calculated as 1:0.55 from the chemical analysis for the sample.

Table 1 - Assays and recoveries "D" Division on "C" ore

| Stream | Wt % | Assay | | | | | | Recovery | | | | | | Sample no. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pb % | Cu % | Zn % | Ag PPM | Fe % | S % | Pb | Cu | Zn | Ag | Fe | S | |
| Ro feed | 100.0 | 0.66 | 0.86 | 6.58 | 240.9 | 21.30 | 21.30 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 5852 |
| Ro conc | 23.34 | 1.04 | 3.05 | 6.65 | 740.7 | 28.03 | 31.07 | 36.6 | 82.6 | 23.6 | 71.8 | 30.7 | 32.2 | 5853 |
| Ro tail | 76.66 | 0.55 | 0.20 | 6.56 | 88.7 | 19.25 | 19.88 | 63.4 | 17.4 | 76.4 | 28.2 | 69.3 | 67.8 | 5854 |
| Midds feed | 31.10 | 0.98 | 3.02 | 6.99 | 814.0 | 29.53 | 33.16 | 45.7 | 108.6 | 33.0 | 105.1 | 43.1 | 45.9 | 5855 |
| Midds conc | 11.94 | 1.75 | 6.59 | 6.50 | 1714.7 | 33.39 | 39.10 | 31.4 | 91.2 | 11.8 | 85.0 | 18.7 | 20.8 | 5856 |
| Midds tail | 19.16 | 0.50 | 0.79 | 7.29 | 252.6 | 27.13 | 29.46 | 14.4 | 17.5 | 21.2 | 20.1 | 24.4 | 25.1 | 5857 |
| $Cl_1$ feed | 35.28 | 1.28 | 4.25 | 6.60 | 1070.3 | 29.84 | 33.79 | 68.0 | 173.7 | 35.4 | 156.8 | 49.4 | 53.0 | 5858 |
| $Cl_1$ conc | 19.31 | 1.69 | 6.22 | 6.20 | 1529.2 | 31.41 | 36.11 | 49.2 | 139.2 | 18.2 | 122.6 | 28.5 | 31.0 | 5859 |
| $Cl_1$ tail | 15.98 | 0.79 | 1.87 | 7.09 | 515.8 | 27.95 | 30.98 | 18.9 | 34.6 | 17.2 | 34.2 | 30.0 | 22.0 | 5860 |
| $Cl_2$ feed | 36.61 | 1.81 | 7.16 | 5.87 | 1804.1 | 32.00 | 36.94 | 99.7 | 303.5 | 32.7 | 274.2 | 55.0 | 60.1 | 5861 |
| $Cl_2$ conc | 21.49 | 2.25 | 9.22 | 5.16 | 2279.3 | 32.56 | 37.99 | 72.8 | 229.4 | 16.9 | 203.3 | 32.8 | 36.3 | 5862 |
| $Cl_2$ tail | 15.12 | 1.18 | 4.23 | 6.88 | 1129.0 | 31.20 | 35.46 | 26.9 | 74.1 | 15.8 | 70.9 | 22.2 | 23.8 | 5863 |
| $Cl_3$ conc | 4.18 | 3.54 | 13.43 | 3.73 | 2975.3 | 32.16 | 38.45 | 22.3 | 65.1 | 2.4 | 51.7 | 6.3 | 7.2 | 5864 |
| $Cl_3$ tail | 17.30 | 1.94 | 8.20 | 3.51 | 2111.0 | 32.66 | 37.87 | 50.5 | 164.3 | 14.5 | 151.6 | 26.5 | 29.1 | 5865 |
| $Cl_4$ conc | 3.65 | 3.51 | 13.81 | 3.53 | 3041.6 | 32.19 | 38.66 | 19.2 | 58.3 | 2.0 | 46.0 | 5.5 | 6.3 | 5866 |
| $Cl_4$ tail | 0.54 | 3.76 | 10.82 | 5.05 | 2527.1 | 31.99 | 38.99 | 3.0 | 6.8 | 0.4 | 5.7 | 0.8 | 0.9 | 5867 |

Table 2 - Assays and recoveries on "B" Division of "A" ore

| Stream | Wt % | Assay | | | | | | Recovery | | | | | | Sample no. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pb % | Cu % | Zn % | Ag PPM | Fe % | S % | Pb | Cu | Zn | Ag | Fe | S | |
| Pr Ro feed | 100.00 | 0.06 | 2.55 | 6.30 | 33.8 | 16.11 | 14.03 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 6219 |
| Pr Ro conc | 12.43 | 0.22 | 17.35 | 7.75 | 173.9 | 26.39 | 31.41 | 48.4 | 84.7 | 15.3 | 63.9 | 20.4 | 27.8 | 6220 |
| Pr Ro tail | 87.57 | 0.03 | 0.45 | 6.09 | 14.0 | 14.65 | 11.56 | 51.6 | 15.3 | 84.7 | 36.3 | 79.6 | 72.2 | 6221 |
| Sec Ro feed | 115.14 | 0.08 | 1.55 | 7.81 | 29.5 | 17.50 | 16.23 | 155.4 | 70.1 | 142.9 | 100.5 | 125.1 | 133.2 | 6222 |
| Sec Ro conc | 14.76 | 0.24 | 8.77 | 12.90 | 121.9 | 26.21 | 31.10 | 64.3 | 50.8 | 30.3 | 53.2 | 24.0 | 32.7 | 6223 |
| Sec Ro tail | 100.37 | 0.05 | 0.49 | 7.07 | 16.0 | 16.22 | 14.05 | 91.1 | 19.3 | 112.7 | 47.3 | 101.1 | 100.5 | 6224 |
| Scav conc on | 1.86 | 0.61 | 5.85 | 16.01 | 82.9 | 27.65 | 34.24 | 20.4 | 4.3 | 4.7 | 4.6 | 3.2 | 4.5 | 6225 |
| Scav conc of | 7.85 | 0.28 | 3.07 | 12.65 | 60.5 | 28.04 | 33.68 | 39.7 | 9.5 | 15.8 | 14.0 | 13.7 | 18.8 | 6226 |
| Scav tail | 90.66 | 0.02 | 0.16 | 6.40 | 10.7 | 14.96 | 11.93 | 31.0 | 5.5 | 92.1 | 28.7 | 84.2 | 77.1 | 6227 |
| $Cl_1$ feed | 32.50 | 0.26 | 11.96 | 11.14 | 139.8 | 26.62 | 31.39 | 153.0 | 152.6 | 57.5 | 134.3 | 53.7 | 72.7 | 6228 |
| $Cl_1$ conc | 19.95 | 0.34 | 16.78 | 9.51 | 188.0 | 27.19 | 32.79 | 121.4 | 131.5 | 30.1 | 110.9 | 33.7 | 46.6 | 6229 |
| $Cl_1$ tail | 12.54 | 0.14 | 4.30 | 13.74 | 63.1 | 25.72 | 29.16 | 31.6 | 21.2 | 27.4 | 23.4 | 20.0 | 26.1 | 6230 |
| $Cl_2$ conc | 12.78 | 0.39 | 21.38 | 7.43 | 222.1 | 27.66 | 33.47 | 39.0 | 107.3 | 15.1 | 83.9 | 22.0 | 30.5 | 6231 |
| $Cl_2$ tail | 7.17 | 0.25 | 8.57 | 13.22 | 127.2 | 26.34 | 31.58 | 32.5 | 24.1 | 15.1 | 27.0 | 11.7 | 16.1 | 6232 |
| $Cl_3$ conc | 9.34 | 0.41 | 25.75 | 5.31 | 258.2 | 27.29 | 34.38 | 69.0 | 94.5 | 7.9 | 71.3 | 15.8 | 22.9 | 6233 |
| $Cl_3$ tail | 3.44 | 0.33 | 9.52 | 13.19 | 124.3 | 28.66 | 31.02 | 20.0 | 12.9 | 7.2 | 12.6 | 6.1 | 7.6 | 6234 |

Table 3 - Galena liberation

| Sample | Division | % free | | % unliberated with pyrite | | % unliberated with sphalerite | |
|---|---|---|---|---|---|---|---|
| | | obs | bal | obs | bal | obs | bal |
| Ro feed | D | 59 | 70 | 20 | | 21 | |
| Ro conc | D | 35 | 51 | 50 | | 15 | |
| Ro tail | D | 82 | 80 | 10 | | 8 | |
| Midds feed | D | 43 | | 40 | | 17 | |
| Midds conc | D | 73 | 62 | 17 | | 10 | |
| Midds tail | D | | 31 | | | | |
| $Cl_1$ feed | D | 35 | | 59 | | 6 | |
| $Cl_1$ conc | D | 62 | 54 | 29 | | 9 | |
| $Cl_1$ tail | D | 58 | 63 | 28 | | 14 | |
| $Cl_2$ conc | D | 64 | 64 | 12 | | 24 | |
| $Cl_2$ tail | D | 28 | 40 | 56 | | 16 | |
| $Cl_3$ conc | D | 63 | 68 | 33 | | 5 | |
| $Cl_3$ tail | D | 49 | 62 | 35 | | 17 | |
| $Cl_4$ feed | D | 69 | 69 | 20 | | 11 | |
| $Cl_4$ tail | D | 58 | 59 | 26 | | 16 | |
| Pr Ro feed | B | 91 | 71 | 9 | 20 | 0 | 9 |
| Pr Ro conc | B | 82 | 96 | 1 | 1 | 17 | 3 |
| Pr Ro tail | B | Nd | 41 | Nd | 45 | Nd | 14 |
| Sec Ro feed | B | 59 | 50 | 18 | 40 | 23 | 10 |
| Sec Ro conc | B | 4 | 44 | 1 | 36 | 95 | 20 |
| Sec Ro tail | B | 10 | 55 | 0 | 42 | 90 | 3 |
| Scav conc on | B | 74 | 79 | 7 | 10 | 19 | 11 |
| Scav conc of | B | 17 | - | 37 | - | 46 | - |
| Scav tail | B | Nd | 32 | Nd | 53 | Nd | 15 |
| $Cl_1$ feed | B | 85 | 73 | 12 | 17 | 3 | 10 |
| $Cl_1$ conc | B | 85 | 87 | 5 | 7 | 10 | 6 |
| $Cl_1$ tail | B | 33 | 31 | 47 | 46 | 20 | 23 |
| $Cl_2$ conc | B | 66 | 91 | 30 | 7 | 4 | 2 |
| $Cl_2$ tail | B | 73 | 75 | 10 | 10 | 17 | 15 |
| $Cl_3$ conc | B | 83 | 96 | 16 | 2 | 1 | 2 |
| $Cl_3$ tail | B | 80 | 79 | 15 | 18 | 5 | 3 |

Nd = not detected

Table 4 - Assays and recoveries due to free and unliberated galena, D Division C ore

| Sample | Assay* due to | | | | Recovery* | | | |
|---|---|---|---|---|---|---|---|---|
| | Pb | free galena | ga in Py | ga in SP | Pb | free ga | ga in Py | ga in SP |
| Ro feed | 0.67 | 0.44 | 0.13 | 0.06 | 100.0 | 69.4 | 20.6 | 10.0 |
| Ro conc | 1.06 | 0.52 | 0.36 | 0.13 | 37.1 | 19.3 | 13.1 | 4.6 |
| Ro tails | 0.55 | 0.41 | 0.06 | 0.04 | 62.9 | 50.1 | 7.5 | 5.4 |
| Midds conc | 1.74 | 0.93 | 0.38 | 0.16 | 31.3 | 17.5 | 7.1 | 3.1 |
| Midds tails | 0.50 | 0.16 | 0.25 | 0.11 | 14.5 | 4.9 | 7.7 | 3.3 |
| $Cl_1$ feed | | | | | 68.4 | 36.7 | 20.3 | 7.9 |
| $Cl_1$ conc | 1.70 | 0.77 | 0.50 | 0.16 | 49.4 | 23.5 | 15.4 | 5.0 |
| $Cl_1$ tails | 0.79 | 0.52 | 0.19 | 0.11 | 19.0 | 13.2 | 4.9 | 2.7 |
| $Cl_2$ conc | 2.26 | 1.25 | 0.36 | 0.35 | 72.9 | 42.5 | 12.1 | 12.0 |
| $Cl_2$ tails | 1.18 | 0.38 | 0.42 | 0.15 | 26.7 | 9.2 | 10.0 | 3.6 |
| $Cl_3$ conc | 3.60 | 2.17 | 0.82 | 0.21 | 22.6 | 14.4 | 5.4 | 1.4 |
| $Cl_3$ tails | 1.93 | 1.03 | 0.24 | 0.39 | 50.2 | 28.1 | 21.6 | 1.8 |
| $Cl_4$ conc | 3.58 | 2.17 | 0.79 | 0.17 | 19.6 | 12.5 | 4.6 | 0.9 |
| $Cl_4$ tails | 3.77 | 2.15 | 1.00 | 0.52 | 3.1 | 1.8 | 0.9 | 0.5 |

* Assays and recoveries of free galena and galena in pyrite in sphalerite should be equal to assays and recoveries for lead. However, since the balance was performed for free galena, Pb, etc. separately the values in each vertical column are consistent, but not in horizontal columns.

Table 5 - Assays and recoveries due to free and unliberated galena B Division on A ore samples

| Sample | Assay* due to | | | | Recovery* | | | |
|---|---|---|---|---|---|---|---|---|
| | Pb | free galena | ga in Py | ga in SP | Pb | free ga | ga in Py | ga in SP |
| Pr Ro feed | 0.056 | 0.032 | 0.011 | 0.005 | 100.0 | 71.2 | 20.0 | 8.8 |
| Pr Ro conc | 0.217 | 0.208 | 0.002 | 0.007 | 48.2 | 53.2 | 0.5 | 1.8 |
| Pr Ro tails | 0.033 | 0.011 | 0.012 | 0.004 | 51.8 | 18.0 | 19.5 | 7.0 |
| Sec Ro feed | 0.076 | 0.031 | 0.025 | 0.006 | 155.8 | 63.3 | 48.8 | 15.0 |
| Sec Ro conc | 0.242 | 0.089 | 0.072 | 0.040 | 63.8 | 23.2 | 18.3 | 12.0 |
| Sec Ro tails | 0.051 | 0.023 | 0.017 | 0.001 | 92.0 | 40.1 | 30.5 | 3.0 |
| Scav conc pans on | 0.657 | 0.555 | 0.068 | 0.077 | 21.8 | 18.4 | 2.2 | 2.9 |
| Scav conc pans off | 0.282 | 0.070 | 0.070 | -0.140 | 39.5 | 9.7 | 9.4 | -7.4 |
| Scav tails | 0.019 | 0.008 | 0.012 | 0.004 | 30.7 | 12.0 | 19.0 | 7.5 |
| $Cl_1$ feed | 0.265 | 0.200 | 0.046 | 0.026 | 153.8 | 115.7 | 25.6 | 17.7 |
| $Cl_1$ conc | 0.342 | 0.292 | 0.025 | 0.018 | 122.0 | 103.8 | 8.6 | 7.7 |
| $Cl_1$ tails | 0.142 | 0.054 | 0.080 | 0.039 | 31.8 | 11.9 | 17.1 | 10.0 |
| $Cl_2$ conc | 0.391 | 0.352 | 0.026 | 0.009 | 89.3 | 80.1 | 5.7 | 2.3 |
| $Cl_2$ tails | 0.255 | 0.185 | 0.024 | 0.037 | 32.7 | 23.7 | 2.9 | 5.4 |
| $Cl_3$ conc | 0.415 | 0.356 | 0.006 | 0.007 | 69.3 | 59.9 | 1.0 | 1.4 |
| $Cl_3$ tails | 0.326 | 0.342 | 0.078 | 0.012 | 20.0 | 20.2 | 4.7 | 0.9 |

* Assays and recoveries of free galena and galena in pyrite in sphalerite should be equal to assays and recoveries for lead. However, the balance was performed for free galena, Pb, etc. separately therefore the values in each vertical column are consistent, but not in the horizontal columns. It is noted that in some cases the recoveries for galena match poorly with the recoveries for lead which indicates that due to the low lead contents of the samples the analyses for free and locked galena in some samples must have had large errors.

Table 6 - Recoveries* by flotation cells

| Flotation cell | Circuit (Division) | Per cent recovery from cell | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Ore (wt) | Cu | Ag | Pb | free galena | galena in pyrite | galena in sphalerite |
| Rougher | D, "C" ore | 23 | 83 | 72 | 37 | 28 | 64 | 46 |
| Cu midds | D, "C" ore | 54 | 84 | 81 | 68 | 78 | 48 | 48 |
| Cleaner 1 | D, "C" ore | 38 | 80 | 78 | 72 | 64 | 75 | 63 |
| Cleaner 2 | D, "C" ore | 59 | 76 | 74 | 73 | 82 | 55 | 72 |
| Cleaner 3 | D, "C" ore | 19 | 28 | 25 | 31 | 34 | 20 | 44 |
| Cleaner 4 | D, "C" ore | 87 | 58 | 89 | 86 | 87 | 84 | 64 |
| Cleaner circuit | D, "C" ore | 10 | 34 | 29 | 29 | 34 | 23 | 11 |
| Pr rougher | B, "A" ore | 12 | 85 | 63 | 48 | 53 | 2 | 20 |
| Sec rougher | B, "A" ore | 13 | 72 | 53 | 41 | 37 | 38 | 80 |
| Scavenger | B, "A" ore | 10 | 71 | 39 | 76 | 54 | 38 | - |
| Cleaner 1 | B, "A" ore | 61 | 86 | 83 | 79 | 90 | 34 | 44 |
| Cleaner 2 | B, "A" ore | 64 | 82 | 76 | 73 | 77 | 66 | 30 |
| Cleaner 3 | B, "A" ore | 91 | 88 | 85 | 78 | 75 | 18 | 61 |
| Cleaner circuit | B, "A" ore | 29 | 62 | 53 | 45 | 51 | 4 | 8 |
| Roughers & scav | B, "A" ore | 9 | 94 | 71 | 69 | 83 | 5 | 15 |

* recovery in concentrate/quantity in feed

Table 7 - Size distributions, all sulphides, "B" Division "A" ore

| Size range µm | 6219 Pr Ro feed | 6220 Pr Ro conc | 6221 Pr Ro tls | 6222 Sec Ro feed | 6223 Sec Ro conc | 6224 Sec Ro tls | 6225 scav conc (on) | 6226 scav conc (off) | 6227 scav tls | 6228 $Cl_1$ feed | 6229 $Cl_1$ conc | 6230 $Cl_1$ tls | 6231 $Cl_2$ conc | 6232 $Cl_2$ tls | 6233 $Cl_3$ conc | 6234 $Cl_3$ tls |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 9.5 | 13.4 | 4.2 | 8.9 | 11.2 | 11.4 | 14.9 | 9.5 | 6.5 | 15.8 | 13.9 | 12.0 | 13.7 | 13.7 | 13.3 | 12.3 |
| 3.3-4.6 | 5.0 | 6.8 | 2.0 | 5.1 | 7.0 | 6.6 | 7.0 | 6.2 | 3.9 | 9.1 | 8.0 | 7.4 | 6.8 | 7.8 | 8.8 | 7.7 |
| 4.6-6.5 | 5.6 | 7.1 | 2.8 | 6.3 | 6.8 | 6.5 | 9.1 | 8.0 | 4.5 | 10.5 | 8.7 | 9.0 | 7.8 | 9.6 | 8.6 | 9.5 |
| 6.5-9.2 | 7.1 | 9.9 | 5.0 | 10.0 | 11.6 | 9.2 | 11.6 | 11.3 | 4.8 | 14.2 | 12.9 | 12.8 | 10.7 | 15.8 | 14.7 | 13.5 |
| 9.2-13 | 9.1 | 9.8 | 5.0 | 9.8 | 12.8 | 7.1 | 14.0 | 12.2 | 6.1 | 13.0 | 13.5 | 14.3 | 12.6 | 13.4 | 12.4 | 15.7 |
| 13-18.5 | 6.2 | 13.6 | 7.5 | 11.4 | 15.4 | 14.1 | 14.9 | 11.2 | 8.3 | 13.0 | 12.0 | 13.8 | 15.3 | 13.8 | 14.3 | 14.9 |
| 18.5-26 | 11.7 | 16.6 | 13.5 | 19.1 | 11.9 | 12.4 | 14.9 | 17.3 | 13.4 | 14.6 | 13.4 | 9.2 | 15.4 | 11.0 | 12.8 | 11.9 |
| +26 | 45.8 | 22.8 | 60.0 | 29.4 | 23.3 | 32.7 | 13.6 | 24.3 | 52.5 | 9.8 | 17.6 | 21.5 | 17.7 | 14.9 | 15.1 | 14.5 |

Table 8 - Size distributions, free galena, "B" Division "A" ore

| Size range µm | 6219 Pr Ro feed | 6220 Pr Ro conc. | 6221 Pr Ro tls | 6222 Sec Ro feed | 6223 Sec Ro conc. | 6224 Sec Ro tls | 6225 scav conc (on) | 6226 scav conc (off) | 6227 scav tls | 6228 $Cl_1$ feed | 6229 $Cl_1$ conc | 6230 $Cl_1$ tls | 6231 $Cl_2$ conc | 6232 $Cl_2$ tls | 6233 $Cl_3$ conc | 6234 $Cl_3$ tls |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 4.7 | 0.5 | | 5.5 | 2.5 | 2.3 | 0.0 | 3.2 | | 1.1 | 2.1 | 2.2 | 1.2 | 0.3 | 0.9 | 1.5 |
| 3.3-4.6 | 0.0 | 3.6 | | 0.0 | 4.6 | 97.7 | 0.0 | 3.6 | | 0.3 | 2.4 | 97.8 | 3.0 | 0.7 | 1.8 | 2.3 |
| 4.6-6.5 | 28.7 | 14.1 | | 0.0 | 17.8 | 0.0 | 0.0 | 0.0 | | 2.9 | 1.9 | 0.0 | 3.1 | 4.9 | 3.1 | 8.5 |
| 6.5-9.2 | 0.0 | 17.1 | | 20.1 | 0.1 | 0.0 | 0.0 | 0.0 | | 5.2 | 6.8 | 0.0 | 5.8 | 10.5 | 21.3 | 18.2 |
| 9.2-13 | 66.6 | 9.5 | | 74.4 | 22.6 | 0.0 | 24.9 | 21.5 | | 2.4 | 22.8 | 0.0 | 6.5 | 18.5 | 28.5 | 19.0 |
| 13-18.5 | 0.0 | 14.8 | | 0.0 | 52.4 | 0.0 | 47.9 | 71.7 | | 8.7 | 6.4 | 0.0 | 41.7 | 10.1 | 19.3 | 20.9 |
| 18.5-26 | 0.0 | 40.4 | | 0.0 | 0.0 | 0.0 | 27.2 | 0.0 | | 21.1 | 20.2 | 0.0 | 16.6 | 18.2 | 25.1 | 29.6 |
| +26 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 58.3 | 37.4 | 0.0 | 22.1 | 36.9 | 0.0 | 0.0 |

Table 9 - Size distributions, galena associated with pyrite, "D" Division "C" ore

| Size range µm | 5852 Ro feed | 5854 Ro tl | 5855 midds feed | 5856a midds conc | 5856b midds conc | 5858 $Cl_1$ feed | 5859 $Cl_1$ conc | 5860 $Cl_1$ tl | 5861 $Cl_2$ feed | 5862 $Cl_2$ conc | 5863 $Cl_2$ tl | 5864 $Cl_3$ conc | 5865 $Cl_3$ tl | 5866 $Cl_4$ conc | 5867 $Cl_4$ tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 2.9 | 14.9 | 6.9 | 1.2 | | 2.6 | 4.2 | 1.0 | 4.4 | 5.8 | 5.3 | 3.5 | 1.3 | 1.0 | |
| 3.3-4.6 | 14.5 | 10.9 | 1.9 | 5.6 | | 3.8 | 10.3 | 2.0 | 4.1 | 0.0 | 4.2 | 2.1 | 2.0 | 3.0 | |
| 4.6-6.5 | 5.6 | 31.0 | 13.5 | 7.2 | | 0.0 | 22.7 | 16.4 | 4.2 | 4.4 | 6.2 | 6.4 | 3.2 | 2.0 | |
| 6.5-9.2 | 35.1 | 0.4 | 23.9 | 35.0 | | 12.3 | 22.8 | 80.6 | 41.8 | 45.7 | 26.7 | 23.5 | 13.1 | 12.0 | |
| 9.2-13 | 41.9 | 43.8 | 13.1 | 51.0 | | 14.0 | 40.0 | 0.0 | 23.4 | 44.1 | 5.2 | 18.1 | 12.6 | 28.0 | |
| 13-18.5 | 0.0 | 0.0 | 40.7 | 0.0 | | 30.1 | 0.0 | 0.0 | 22.1 | 0.0 | 52.4 | 23.9 | 33.5 | 54.0 | |
| 18.5-26 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 22.5 | 34.3 | 0.0 | |
| +26 | 0.0 | 0.0 | 0.0 | 0.0 | | 37.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |

Table 10 - Size distributions, galena associated with sphalerite, "D" Division "C" ore

| Size range µm | 5852 Ro feed | 5854 Ro tl | 5855 midds feed | 5856a midds conc | 5856b midds conc | 5858 $Cl_1$ feed | 5859 $Cl_1$ conc | 5860 $Cl_1$ tl | 5861 $Cl_2$ feed | 5862 $Cl_2$ conc | 5863 $Cl_2$ tl | 5864 $Cl_3$ conc | 5865 $Cl_3$ tl | 5866 $Cl_4$ conc | 5867 $Cl_4$ tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 3.8 | 6.1 | 12.1 | 1.5 | | 6.3 | 11.0 | 10.3 | 16.1 | 1.0 | 1.5 | 15.1 | 0.1 | 3.0 | |
| 3.3-4.6 | 3.7 | 12.4 | 2.7 | 2.6 | | 19.0 | 25.1 | 19.2 | 36.5 | 1.6 | 0.2 | 14.2 | 3.1 | 2.3 | |
| 4.6-6.5 | 33.1 | 0.0 | 40.0 | 8.3 | | 0.1 | 25.1 | 0.2 | 47.4 | 0.1 | 0.0 | 8.6 | 10.0 | 16.5 | |
| 6.5-9.2 | 26.4 | 33.8 | 0.0 | 17.9 | | 0.0 | 38.8 | 0.1 | 0.0 | 0.0 | 7.8 | 15.1 | 24.7 | 0.0 | |
| 9.2-13 | 33.0 | 47.7 | 45.1 | 69.7 | | 74.6 | 0.0 | 70.2 | 0.0 | 26.3 | 0.0 | 50.0 | 0.0 | 0.0 | |
| 13-18.5 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 62.1 | 78.2 | |
| 18.5-26 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 90.5 | 0.0 | 0.0 | 0.0 | |
| +26 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 71.0 | 0.0 | 0.0 | 0.0 | 0.0 | |

Table 11 - Size distributions, all sulphides, "D" Division "C" ore

| Size range µm | 5852 Ro feed | 5854 Ro tl | 5855 midds feed | 5856a midds conc | 5856b midds conc | 5858 $Cl_1$ feed | 5859 $Cl_1$ conc | 5860 $Cl_1$ tl | 5861 $Cl_2$ feed | 5862 $Cl_2$ conc | 5863 $Cl_2$ tl | 5864 $Cl_3$ conc | 5865 $Cl_3$ tl | 5866 $Cl_4$ conc | 5867 $Cl_4$ tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 11.3 | 7.5 | 13.9 | 8.4 | 7.9 | 9.5 | 12.8 | 13.1 | 83.2 | 11.9 | 12.5 | 13.9 | 17.4 | 13.0 | 12.7 |
| 3.3-4.6 | 2.8 | 4.6 | 7.7 | 7.2 | 5.6 | 7.0 | 7.5 | 8.0 | 1.4 | 7.2 | 6.6 | 7.6 | 8.1 | 8.3 | 7.6 |
| 4.6-6.5 | 8.1 | 6.0 | 9.1 | 7.7 | 5.4 | 7.4 | 8.8 | 9.3 | 1.8 | 9.2 | 8.4 | 8.6 | 11.5 | 9.9 | 7.3 |
| 6.5-9.2 | 4.9 | 7.0 | 12.3 | 14.1 | 8.3 | 12.6 | 12.7 | 12.8 | 2.2 | 11.9 | 10.2 | 12.0 | 12.3 | 12.8 | 12.0 |
| 9.2-13 | 9.6 | 5.9 | 11.8 | 10.2 | 8.8 | 13.9 | 13.5 | 13.5 | 2.1 | 13.1 | 10.7 | 14.9 | 15.1 | 13.0 | 15.2 |
| 13-18.5 | 15.2 | 10.6 | 18.8 | 17.0 | 17.2 | 8.8 | 12.7 | 18.8 | 3.1 | 14.8 | 12.5 | 13.7 | 16.9 | 17.4 | 17.5 |
| 18.5-26 | 15.5 | 13.2 | 15.9 | 16.6 | 9.1 | 11.3 | 14.7 | 17.2 | 2.5 | 12.8 | 15.2 | 13.4 | 11.0 | 14.8 | 15.5 |
| +26 | 32.6 | 45.2 | 10.5 | 18.8 | 37.7 | 29.5 | 14.3 | 7.3 | 3.7 | 19.1 | 23.9 | 15.9 | 7.7 | 10.8 | 12.2 |

Table 12 - Size distributions, free galena, "D" Division "C" ore

| Size range µm | 5852 Ro feed | 5854 Ro tl | 5855 midds feed | 5856a midds conc | 5856b midds conc | 5858 $Cl_1$ feed | 5859 $Cl_1$ conc | 5860 $Cl_1$ tl | 5861 $Cl_2$ feed | 5862 $Cl_2$ conc | 5863 $Cl_2$ tl | 5864 $Cl_3$ conc | 5865 $Cl_3$ tl | 5866 $Cl_4$ conc | 5867 $Cl_4$ tl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 0.8 | 0.8 | 6.0 | 3.3 | | 4.0 | 9.3 | 3.3 | 6.5 | 5.8 | 9.7 | 6.9 | 4.6 | 2.3 | 1.7 |
| 3.3-4.6 | 3.2 | 0.0 | 1.5 | 4.0 | | 6.7 | 7.7 | 5.1 | 4.7 | 5.4 | 3.1 | 8.0 | 5.6 | 3.5 | 3.9 |
| 4.6-6.5 | 1.2 | 3.3 | 10.7 | 2.7 | | 7.7 | 8.4 | 14.0 | 11.8 | 8.2 | 7.6 | 7.9 | 9.7 | 10.7 | 5.6 |
| 6.5-9.2 | 4.5 | 11.3 | 42.2 | 8.0 | | 10.9 | 15.6 | 7.6 | 10.7 | 18.3 | 0.2 | 12.9 | 5.9 | 20.9 | 12.2 |
| 9.2-13 | 10.3 | 4.4 | 39.5 | 11.0 | | 37.0 | 18.7 | 15.5 | 23.6 | 20.2 | 25.8 | 29.3 | 24.6 | 23.6 | 20.0 |
| 13-18.5 | 28.7 | 18.3 | 0.0 | 15.3 | | 0.1 | 21.4 | 0.0 | 42.7 | 27.0 | 53.6 | 12.5 | 49.6 | 29.3 | 19.4 |
| 18.5-26 | 51.3 | 34.8 | 0.0 | 55.7 | | 33.6 | 18.9 | 15.5 | 0.0 | 15.1 | 0.0 | 0.0 | 0.0 | 9.7 | 37.2 |
| +26 | 0.0 | 27.1 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 22.5 | 0.0 | 0.0 | 0.0 |

Table 13 - Size distributions, galena associated with pyrite, "B" Division "A" ore

| Size range µm | 6219 Pr Ro feed | 6220 Pr Ro conc | 6221 Pr Ro tls | 6222 Sec Ro feed | 6223 Sec Ro conc | 6224 Sec Ro tls | 6225 scav conc (on) | 6226 scav conc (off) | 6227 scav tls | 6228 $Cl_1$ feed | 6229 $Cl_1$ conc | 6230 $Cl_1$ tls | 6231 $Cl_2$ conc | 6232 $Cl_2$ tls | 6233 $Cl_3$ conc | 6234 $Cl_3$ tls |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | 0.0 | 100.0 | | 18.5 | 0.0 | | 0.0 | 1.6 | | 1.4 | 0.0 | 0.0 | 2.0 | 0.1 | 2.8 | 4.3 |
| 3.3-4.6 | 100.0 | 0.0 | | 0.0 | 0.1 | | 23.4 | 1.6 | | 2.1 | 0.0 | 0.0 | 1.0 | 21.4 | 0.3 | 15.6 |
| 4.6-6.5 | 0.0 | 0.0 | | 0.5 | 51.4 | | 46.4 | 15.9 | | 0.1 | 20.9 | 0.6 | 2.7 | 8.4 | 14.0 | 13.8 |
| 6.5-9.2 | 0.0 | 0.0 | | 81.0 | 48.5 | | 30.2 | 4.4 | | 9.2 | 79.1 | 99.4 | 0.0 | 70.1 | 16.4 | 19.8 |
| 9.2-13 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | 31.3 | | 0.0 | 0.0 | 0.0 | 24.9 | 0.0 | 66.5 | 0.2 |
| 13-18.5 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | 0.1 | | 0.0 | 0.0 | 0.0 | 21.1 | 0.0 | 0.0 | 46.3 |
| 18.5-26 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | 45.1 | | 87.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| +26 | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 48.2 | 0.0 | 0.0 | 0.0 |

Table 14 - Size distributions, galena associated with sphalerite, "B" Division "A" ore

| Size range µm | 6219 Pr Ro feed | 6220 Pr Ro conc | 6221 Pr Ro tls | 6222 Sec Ro feed | 6223 Sec Ro conc | 6224 Sec Ro tls | 6225 scav conc (on) | 6226 scav conc (off) | 6227 scav tls | 6228 $Cl_1$ feed | 6229 $Cl_1$ conc | 6230 $Cl_1$ tls | 6231 $Cl_2$ conc | 6232 $Cl_2$ tls | 6233 $Cl_3$ conc | 6234 $Cl_3$ tls |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| minus 3.3 | | 5.6 | 0.6 | 27.0 | 9.5 | | 2.3 | 0.1 | | 6.0 | 0.0 | 0.0 | 3.3 | 2.1 | 1.0 | 14.2 |
| 3.3-4.6 | | 0.0 | 15.7 | 16.1 | 6.9 | | 0.0 | 3.0 | | 0.0 | 0.0 | 100.0 | 6.7 | 0.3 | 1.1 | 29.2 |
| 4.6-6.5 | | 9.0 | 0.0 | 0.0 | 10.2 | | 0.1 | 11.5 | | 0.0 | 7.8 | 0.0 | 90.0 | 12.2 | 97.9 | 0.1 |
| 6.5-9.2 | | 28.6 | 83.7 | 56.9 | 11.6 | | 15.7 | 16.0 | | 36.7 | 15.6 | 0.0 | 0.0 | 37.5 | 0.0 | 56.5 |
| 9.2-13 | | 56.8 | 0.0 | 0.0 | 6.9 | | 20.3 | 28.5 | | 57.3 | 76.6 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 13-18.5 | | 0.0 | 0.0 | 0.0 | 16.5 | | 61.6 | 40.9 | | 0.0 | 0.0 | 0.0 | 0.0 | 47.8 | 0.0 | 0.0 |
| 18.5-26 | | 0.0 | 0.0 | 0.0 | 19.6 | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| +26 | | 0.0 | 0.0 | 0.0 | 18.8 | | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

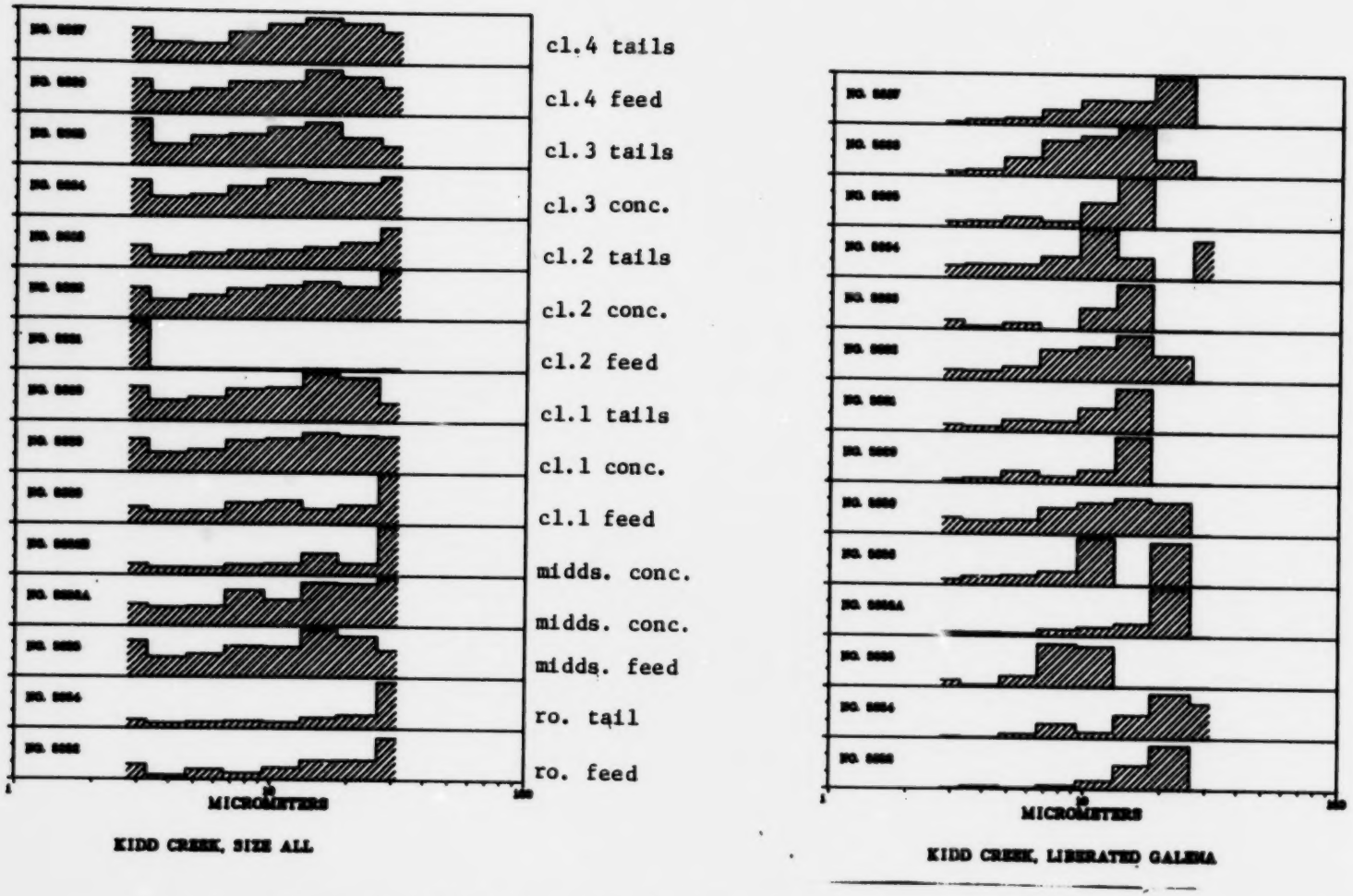


Fig. 1. Histograms showing size distributions of the grains (left diagram) and of the free galena (right diagram) in samples from "D division on C ore". The histograms are plotted as amount in each Tyler mesh size range. The vertical scale is different for each sample, it uses the highest value of the size analysis data for each sample as the maximum and scales all other values proportionally.

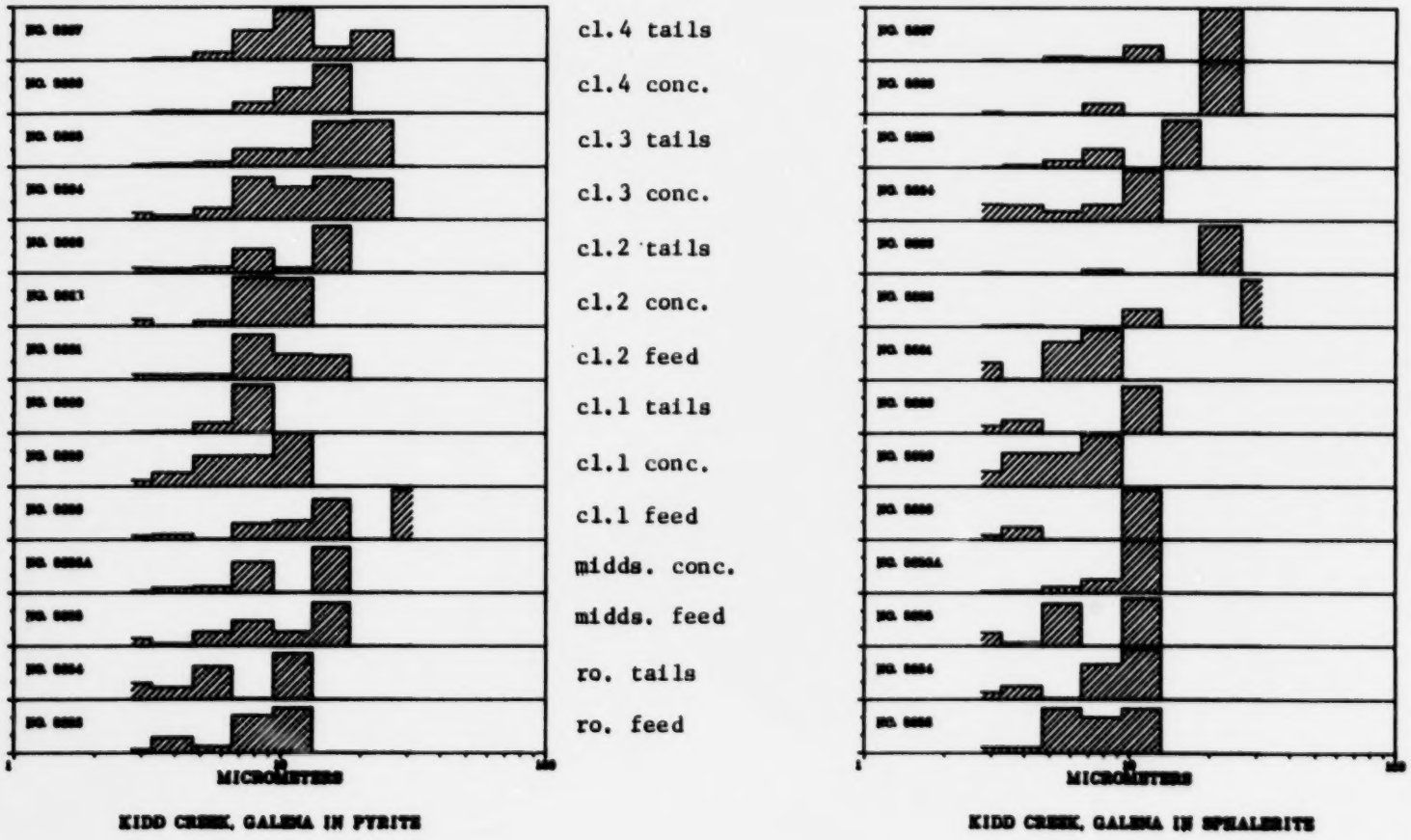


Fig. 2. Histograms showing size distributions of galena that is either combined with or locked in pyrite (left diagram) and sphalerite (right diagram). Plotted as in Figure 1. "D division on core".

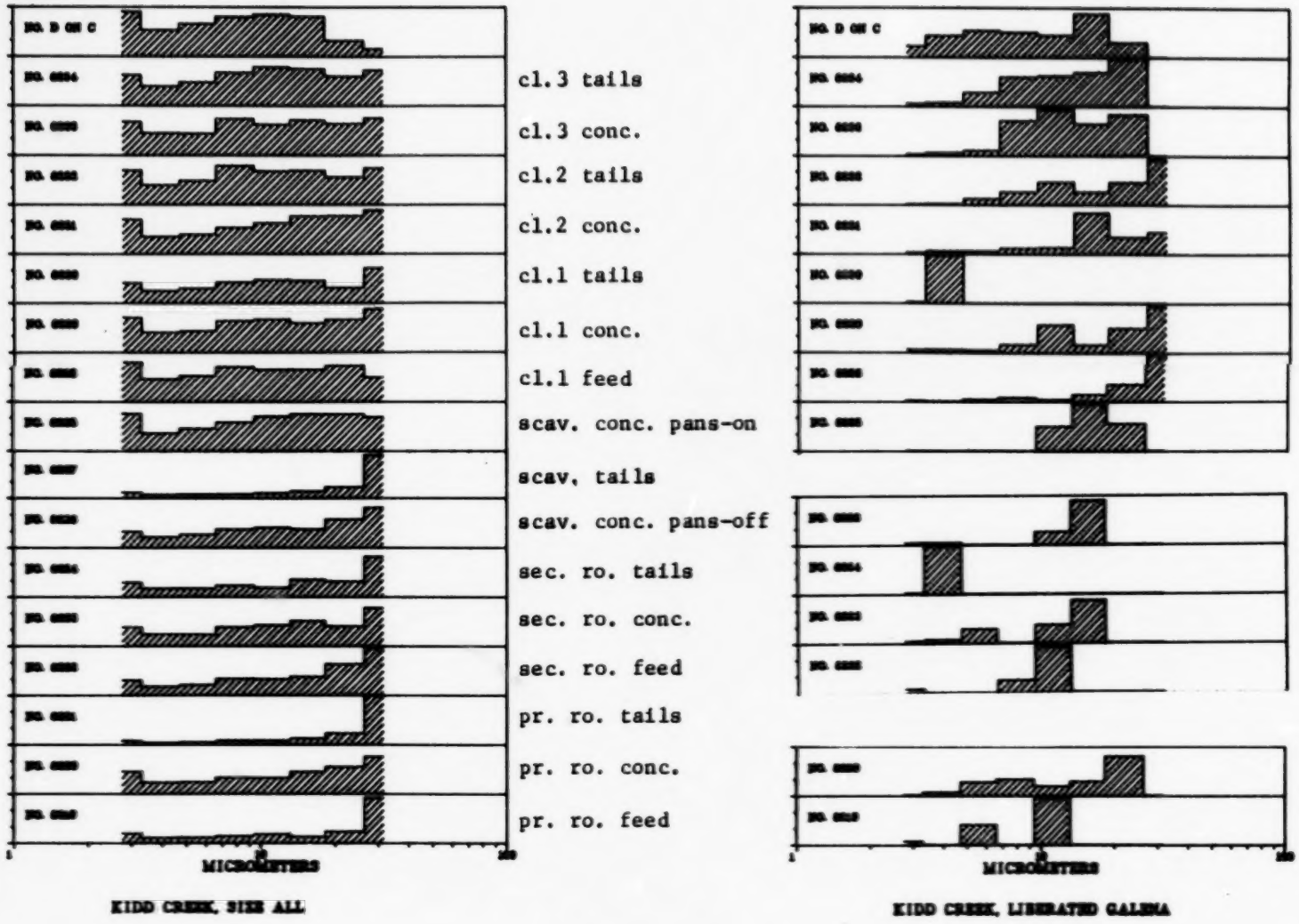


Fig. 3. Histograms showing size distributions of grains (left diagram) and of free galena (right diagram) in samples from "B division on A ore". Plotted as in Figure 1.

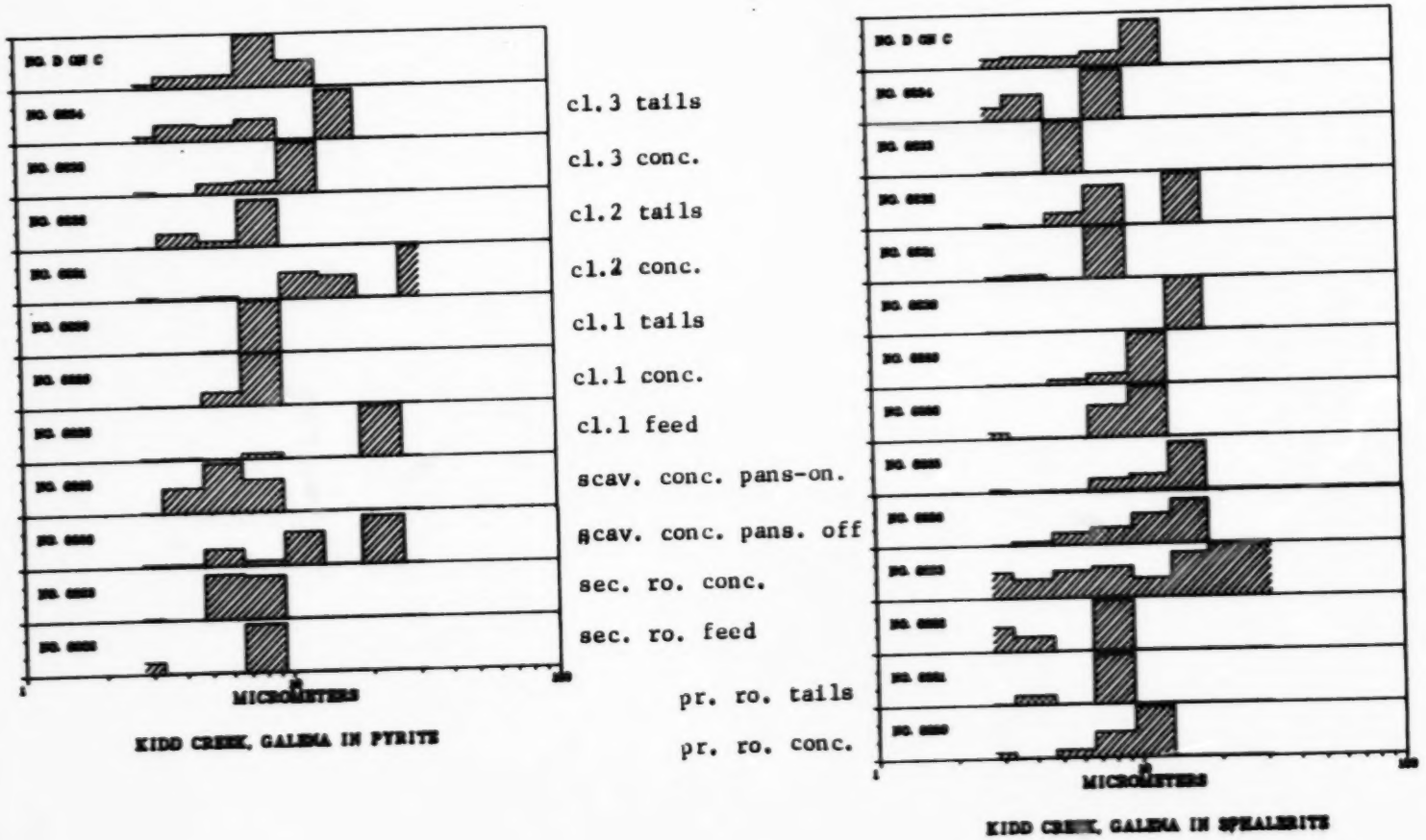


Fig. 4. Histograms showing size distributions of galena that is either combined with or locked in pyrite (left diagram) and sphalerite (right diagram). Plotted as in Figure 1. "B division on A ore".